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AN INVESTIGATION INTO THE SOURCE OF ERROR IN STADIMETRIC RANGE --ETC(U)
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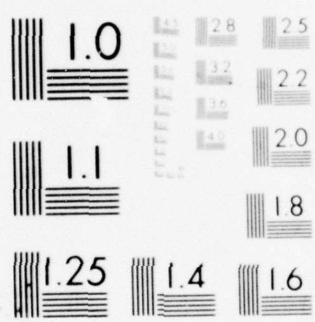

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An Investigation into the Source of

Error in Stadimetric Range Estimation

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An Investigation into the Source of Error in Stadimetric Range Estimation

Previous studies (McClusky, 1971; McClusky, Wright, and Frederickson, 1968) have obtained data on the use of a simple stadimetric device as a ranging aid or range-finder. This device functions by allowing the observer to measure the apparent wingspan of an aircraft by matching it with a standard. If the real size of the aircraft is known, computation using the visual angle will reveal the range of the target. The most extensive of these studies (McClusky, et al., 1968) used a weapon mock-up with a chin-rest which fixed the distance from the eye to the standard. This study used a reduced scale simulation which yielded smaller mean errors and less variability when compared to field results. A striking finding was a statistically significant difference in error between the incoming and outgoing targets, with the outgoing targets being associated with a large error of underestimation.

McClusky's results also revealed large, apparently stable, individual differences in the ability to estimate range accurately. Subsequent work by Ton (1972) also revealed significant variation in accuracy among individuals.

Experiment I

In an attempt to identify a source of these observed individual differences, it was hypothesized that accurate anticipation of the coincidence event is related to accuracy in time estimation.

Correct anticipation is seen as largely based on an accurate interpolation of target velocity based on its movement history. Perception of target velocity is in turn hypothesized to be based on the observer's internal "time sense." Therefore, an individual who possesses an accurate "time sense" should excel at this range estimation task. Accordingly, an experiment was designed to investigate the possible relationship between time perception and range estimation. To provide a criterion for the accuracy of "time sense," a task was devised which would measure an individual's ability to accurately estimate a filled time interval. In addition, two other variables were included in the analysis: Critical Flicker Frequency (CFF) as a measure of the general efficiency of the visual system, and the Embedded Figures Test (EFT) as a measure of perceptual style or field dependence/independence.

Method

Range Estimation (RE). The equipment used to derive range estimation data consisted of an oscilloscope driven by a variable frequency oscillator. The oscilloscope displayed a moving bar target which simulated an aircraft in flight to or away from the observer's eye. Target motion was controlled by a motor which varied the oscillator voltage. The motor controls were designed to produce a wide range of angular expansion rates which would allow simulation of a wide range of target speeds. The shape of the bar target approximated in width and thickness an F-100 aircraft and expanded pro-

portionally. The oscilloscope was placed at one end of a seven-foot long light-tight box. An internally illuminated plexiglass post was placed part way down the box where it subtended an angle equal to the target at a scale distance of 1500 meters. The target size and distance values were the same as those used by McClusky (1971). The observer was seated at the opposite end of the box and observed the target and post monocularly through a 1X terrestrial telescope to eliminate accommodation cues. Viewing was with the dominant eye in all cases. To minimize observer fatigue, an adjustable chin-rest was provided. The beginning of a trial was signaled to the observer by an indicator light. After approximately three seconds, the target appeared in motion at a scale distance of either 500 or 2500 meters, depending on whether an outgoing or incoming trial was being presented. The target appeared to move long the line-of-sight to or from the observer's eye at a scale rate of 400 knots. The experimental task was to signal the coincidence event (i.e., when the size of the bar target was seen to coincide with the illuminated post) by closing a switch. After 10 practice trials, the observer received 50 trials -- 25 incoming and 25 outgoing -- in a random order. The observer's judgment was presented to the experimenter by a digital voltmeter. Circuitry associated with the voltmeter converted the oscilloscope voltage to target range. The readout was to the nearest 10 meters (±.1%).

Time Estimation (TE). The time estimation equipment consisted of a digital counter which could be used to present a signal of known duration to the subject with very high accuracy and repeat-

ability. An auditory signal was used for the present work. The tone used had a fundamental frequency of 2500 hz presented at an average Sound Pressure Level (SPL) of 75 dB. The subject was required to duplicate filled intervals of 8, 11, and 16 seconds. These intervals were selected because they were near the actual movement duration and were of odd size to avoid any anchor effects which might occur if a "familiar" interval (i.e., five or ten seconds) was used. The tone was presented to the subject for the desired interval. The subject was then required to duplicate the presented interval by pressing a switch, then perform a number cancellation task. When the subject judged the interval to be over, he signaled by again pressing the switch. The observer's estimate was transmitted to the experimenter by an electric stop-clock. The instructions placed emphasis on accuracy in performing the interpolated task and were intended to prevent the observer from estimating time by counting.

Each observer was given three practice trials, one for each interval. Following this, the observer received ten trials per interval. The order of presentation was randomized.

Critical Flicker Frequency (CFF). Critical flicker frequency determination was performed for each experimental subject. The apparatus consisted of a variable speed sector disc which interrupted a light source to provide a wide range of pulsed flicker. The sector disc could be adjusted to vary the light-to-dark ratio of the stimulus. For the present usage, the disc was adjusted to

give equal light and dark periods. A circular flickering field subtending two degrees of visual angle was presented against an illuminated surround subtending 30 degrees. A dark fixation point was provided in the center of the test field. To maintain photopic vision, the illumination of both the flickering target and its surround was fixed at 40-foot Lamberts. These stimulus parameters were recommended by Rey (1971) to ensure reliability of measurement by accepted standard practice. The method of limits was used -- each observer was given four practice trials (two ascending and two descending) followed by ten criterion trials. The trials were separated into blocks of five which were separated by a 30-second rest period. The direction of the trials was randomized.

Embedded Figures Test (EFT). The EFT (Dees, O'Reilly, and Sennett, 1969) was administered to all observers. This instrument has been found to be a measure of "perceptual style." The EFT orders individuals along a continuum from "field dependence" to "field independence" (Witkin, Lewis, Hertzman, Machover, Meissner, and Wapner, 1954). Field independent individuals are relatively proficient in picking out isolated features embedded in a complex field. Earlier work by the author (Ton, 1972a, b) has shown small but consistent relationships between perceptual style and performance in tasks involving radial motion. The EFT in its current revision consists of 24 items and requires ten minutes for administration.

The subjects were US Army enlisted men drawn from training brigades at Fort Bliss, Texas. Approximately 135 individuals were

screened with a Bausch and Lomb (B&L) Orthorater to yield a sample of 67 subjects with a mean near acuity of 20-20.852 and a mean far acuity of 20-20.098. Individuals with either near or far acuity of less than 20-30 were rejected.

Analysis and Results

A mean algebraic error was calculated for both the range estimation and the time estimation data for each observer's set of trials. Algebraic error is defined as the bias of deviation of the judged quantity from the standard. This measure provides both magnitude and the direction of error. Thus, the extent of over- or underestimation can be known. Overestimation would occur if the reference post was at 1500 meters and the subject signaled the coincidence event when the actual target range was 1600 meters. This judgment would be recorded as an overestimation of 100 meters (+100). Underestimation would occur when, under the same conditions, the observer reported the coincidence event when the target was actually at 1400 meters. This would be recorded as an error of underestimation (-100). Over- and underestimation for time estimation was defined in a similar fashion. Dispersion Indices (DI) were then computed for the range estimation and time estimation data. The DI provides a measure of the overall accuracy of a set of measurements by combining the mean algebraic (accuracy) and the variance (consistency) associated with the mean. The DI is calculated (Frederickson, Follettie, and Baldwin, 1967) as follows:

$$DI = (\text{mean algebraic error})^2 + (\text{standard deviation})^2$$

Summary statistics for the various measures employed are given in Table 1. It should be noted that this data, like the earlier work, exhibits a relatively high error of underestimation for the outgoing target. The small mean algebraic error for the time estimation tasks should also be noted. The relatively large standard deviations associated with the RE and time measures indicate considerable individual differences in performance of these tasks. The CFF data show less variation and, in the writer's experience, are typical of the performance of individuals drawn from the general population. The mean and variance of the EFT scores are generally similar to those obtained from other samples drawn from the Army population. No general population norms are currently available for any of the measures used in these studies.

Insert Table 1 About Here

A Pearson Product Moment Correlation was computed for all pairs of variables. The resulting correlation matrix is given in Table 2 along with the associated t and p values with the degrees of freedom for each variable pair.

Insert Table 2 About Here

Of particular interest for the current investigation are the first three correlations found on Table 2 (i.e., those between the

three DIs of time estimation -- DI TE; and the DI for range estimation -- DI RE). The low magnitude of these correlations indicates the lack of a significant relationship between the measures of time perception used and performance in the range estimation task. Examination of the correlations between RE and the remaining variables presents a similar picture of no significant relationship. Of the inter-correlation between the various predictors, only five reached acceptable levels of significance. The DIs for the three time intervals are highly related, which may indicate the existence of a common mechanism underlying estimation of these intervals. The remaining two significant correlations, those between EFT and DI_{16} seem to indicate that field independent individuals are more accurate in estimating longer time intervals, a finding of little interest got the present investigation.

Experiment II

Method

The experimental procedures will not be discussed in detail as Experiment II differed from Experiment I only in the manner of experimental controls as follows:

1. No screening for visual acuity,
2. Calibration of the RE equipment morning and noon,
3. Elimination of the 1X telescope (subjects had complained of the limited eye relief and difficulty in keeping the standard in view),
4. Greater emphasis on adherence to experimental procedures.

As in Experiment I, the subjects were drawn from the training battalions at Fort Bliss, Texas. None of these 64 observers had participated in the earlier experiment. No visual acuity screening was carried out as it was felt that the restriction in acuity range might be affecting the magnitude of the correlations. However, despite the lack of restriction on visual acuity, this group was similar to the earlier group with a far acuity of 20-20.32 and a mean near acuity of 20-21.05. Variability was somewhat greater with standard deviations of 5.57 and 4.41 for far and near acuity, respectively.

Analysis and Results

The means and standard deviations of RE and TE (Table 3) show that this group of observers was somewhat more accurate in their judgments than the earlier group. These differences may be due to changes in experimental control; however, these differences are small and there is no way to separate control factors from the random changes expected from using another sample. The CFF and EFT mean

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Insert Table 3 About Here

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scores and standard deviation differ little between Experiments I and II. This might be expected as these tasks were by far the simplest to administer.

As in Experiment I, Pearson Product Moment Correlations were computed between all pairs of variables. These are reproduced in Table 4. A comparison of these correlations with those from Experiment II shows some shifting around of the sign and magnitude of the correlations. However, a similar overall picture emerges, that of no significant correlation between accuracy in range estimation and any of the five other variables. The inter-correlations between the DIs of the three time intervals remain positive and highly significant. As in Experiment I, a significant negative correlation was exhibited between field independence and ability to estimate the longer time interval.

Insert Table 4 About Here

The zero order correlations were then used to compute a linear multiple regression with a resulting R of .339. Therefore, approximately 11 percent of the variation in range estimation is accounted for by the variance of the other five variables; however, it does not achieve statistical significance at accepted confidence levels. Thus, the obtained result fails to achieve either practical or statistical significance.

Discussion and Conclusions

From the experiments performed in the course of these investigations, it seems clear that little was revealed concerning the

mechanism responsible for the differences in error between incoming and outgoing targets. There is no evidence for a significant relationship between range estimation, accuracy, time estimation (for the intervals used), CFF, and perceptual style. Thus, although the problem seems unsolved, it can be stated with some confidence what factors are not involved, but the nugget of truth still evades discovery.

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TABLE 1

EXPERIMENT II
MEANS AND STANDARD DEVIATIONS FOR THE MEASURES

	$\overline{X}$	σ
Range Estimation D.I.	207.16	46.50
Time Estimation:		
D.I.$_8$	3.030	2.730
D.I.$_{11}$	3.360	2.860
D.I.$_{16}$	3.700	1.970
CFF $\overline{X}$	43.631	3.083
EFT Score	11.492	6.237
Range Estimation:		
$\overline{X}_I$	1473.51	8.615
$\overline{X}_0$	1282.20	8.828
Mean Algebraic Error:		
$\Sigma\overline{X}_{RE}$	-121.43	6.499
$\overline{X}_8$	1.561	2.874
$\overline{X}_{11}$	1.214	3.152
$\overline{X}_{16}$	-1.870	2.690

TABLE 2

EXPERIMENT II
CORRELATION AND PLUS VALUES FOR ALL PAIRS OF VARIABLES

Variables	σ	+	*df*	*p* (one tailed)
RE DI vs. TE DI_8	-.132	-1.077	65	
RE DI vs. TE DI_{11}	-.097	-.789	65	
RE DI vs. TE DI_{16}	-.017	-.138	65	
RE DI vs. CFF $\overline{X}$	-.084	-.682	65	
RE DI vs. EFT	-.102	-.830	65	
TE DI_8 vs. TE DI_{11}	+.885	+15.329	65	<.0005
TE DI_8 vs. TE DI_{16}	+.676	+7.408	65	<.0005
TE DI_{11} vs. TE DI_{16}	+.792	+10.486	65	<.0005
TE DI_8 vs. CFF	+.009	+.080	65	
TE DI_{11} vs. CFF	+.019	+.154	65	
TE DI_{16} vs. CFF	+.065	+.525	65	
TE DI_8 vs. EFT	-.171	-1.405	65	
TE DI_{11} vs. EFT	-.232	-1.925	65	<.0500
TE DI_{16} vs. EFT	-.278	-2.333	65	<.0250
CFF vs. EFT	+.070	+.568	65	

TABLE 3

EXPERIMENT II
MEANS AND STANDARD DEVIATIONS FOR ALL MEASURES

	$\overline{X}$	σ
Range Estimation D.I.	173.40	4.960
Time Estimation:		
$D.I._8$	2.160	2.170
$D.I._{11}$	2.300	2.210
$D.I._{16}$	3.100	1.820
CFF $\overline{X}$	43.530	3.180
EFT Score	10.310	6.560
Range Estimation:		
$\overline{X}_I$	1497.80	112.70
$\overline{X}_0$	1367.00	89.20
Mean Algebraic Error:		
$\Sigma\overline{X}_{RE}$	-6.780	7.790
$\overline{X}_8$	0.030	2.010
$\overline{X}_{11}$	0.290	2.340
$\overline{X}_{16}$	-1.000	1.920

TABLE 4

EXPERIMENT II
CORRELATION AND t VALUES FOR ALL PAIRS OF VARIABLES

Variables		σ	t	*df*	*p* (one tailed)
RE DI	vs. TE DI_8	.053	.420	62	
RE DI	vs. TE DI_{11}	.184	1.477	62	
RE DI	vs. TE DI_{16}	.235	1.910	62	
RE DI	vs. CFF $\bar{X}$	-.055	-.435	62	
RE DI	vs. EFT	.011	.092	62	
TE DI_8	vs. TE DI_{11}	.742	8.719	62	<.001
TE DI_8	vs. TE DI_{16}	.730	8.429	62	<.001
E DI_{11}	vs. TE DI_{16}	.799	10.468	62	<.0005
TE DI_8	vs. CFF	-.046	-.369	62	
TE DI_{11}	vs. CFF	-.090	-.718	62	
TE DI_{16}	vs. CFF	-.098	-.782	62	
TE DI_8	vs. EFT	-.218	-1.763	62	
TE DI_{11}	vs. EFT	-.251	-2.047	62	<.05
TE DI_{16}	vs. EFT	-.359	-3.033	62	<.01
CFF	vs. EFT	-.115	-.915	62	

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From the experiments performed in this investigation, little was revealed concerning the mechanism responsible for the differences in error between incoming and outgoing targets. There is no evidence for a significant relationship between range estimation, accuracy, time estimation (for the intervals used), CFF and perceptual style.

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